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March 2000 Working Group Meeting
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Introduction

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Presentations were given by representatives from the Department of Energy (DOE) Office of Transportation Technology Office of Heavy Vehicle Technology (OHVT), LLNL, SNL, NASA Ames, USC, and Caltech. Representatives from Argonne National Laboratory also participated via telephone. This report contains the technical presentations (viewgraphs)

March 2000
Working Group Meeting on
Heavy Vehicle Aerodynamic Drag:

Presentations and Summary of Comments and Conclusions

Jointly written by
Lawrence Livermore National Laboratory
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Introduction

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delivered at the Meeting, briefly summarizes the comments and conclusions, and outlines the future action items.

Summary of Major Issues

There were 3 major issues raised at the meeting.

1. Our funding is inadequate to satisfy industries request for high Reynolds number experimentation and computation. Plans are to respond to the DOD and DOE requests for proposals, which require a 50-50 cost share with industry, to acquire funding for high Reynolds number experiments at NASA Ames.
2. The deficiencies in commercial software, the need for model improvements and validation, and the unavailability of a detailed database for advanced model validation needs to be recognized.
3. The need for industrial collaboration appears to be a requirement for acquiring funding.

Overview of the Project, Current Funding, and Future Workshop

Jules Routbort of DOE OHVT and Argonne National Laboratory provided an overview of the OHVT budget from fiscal year (FY) 1997 through FY00 for heavy vehicle systems aerodynamic drag reduction. For projects involving heavy vehicle systems parasitic energy losses, OHVT has requested a total of $4.5 million for FY01 with an additional $1.5 million for the solicitation of industry proposals on parasitic energy losses. The Aero Team's estimated costs for FY 2001 is over $1.5 million, because of the high cost for needed NASA experiments. This would require almost all of the OHVT's total budget for parasitic energy losses, which is not a reasonable expectation. Rather than an increase in funding, Jules presented a possible scenario for funding reduction for this project.

Jules emphasized that stable funding for our computational and experimental effort will require industrial support. Future funding through formal requests for proposals (under competitive bid) will likely require a 50-50 cost share from industry. Jules stated that commercial software companies have indicated that they can do what the Aero Team is pursuing. This comment set the tone for much debate, with the Aero Team providing evidence of needed model development, advanced computational resources, and experimental data for code validation. Without benchmarking and validation in a careful systematic approach, the correctness or accuracy of computations are unknown.

An overview of the project was presented by Rose McCallen of LLNL. The viewgraphs are enclosed. Budget issues were presented as well as the project calendar of events and plans for submitting proposals for needed funding. It was emphasized that several of the team participants (USC, Caltech, and NASA) had still not received or had just recently received the expected FY00 funds. Specifically, NASA had not received any funds and thus all testing was on hold and scheduling of tests for FY00 was in jeopardy.

It was emphasized that the program deliverables are being met only because of the team's

success in leveraging funds from internal research support (e.g., LDRD and Tech Base at the National Labs) and the support of other agencies (e.g., DOD, Caltrans, NSF, ASCI) for related work.

NASA's Plans for 7-ft x 10-ft Wind Tunnel Experiments in FY00 and Future Plans for 12-ft Wind Tunnel Experiments

Jim Ross of NASA Ames presented options for the 7-ft x 10-ft wind tunnel tests which include experiments with a modified GTS model or use of a 1/8th scale model from International Transportation Corporation. NASA's plans also include provisions for USC to test their GTS model in the 7-ft x 10-ft wind tunnel for evaluation at lower blockage and higher Reynolds number flow. The purpose of all these experiments are for validation of the computational fluid dynamics (CFD) models and for further insight into truck flow phenomena.

Jim also presented details of the high Reynolds number experiments proposed for the 12-ft pressure wind tunnel. These experiments will provide answers to scaling issues as well as a database for code validation. Details are provided in the attached viewgraphs. The truck industry is very interested in these tests because they recognize that there are discrepancies between the Re effects experienced with a full-size truck and that predicted by experiment on scaled down models in wind tunnels.

The expected costs for the 12-ft wind tunnel experiments are at a 1/3rd reduced cost for a government funded effort. NASA is not charging for salaries. An additional $240K could have been saved if the experiments had been performed in FY00. The sooner these experiments can be scheduled, the less the cost. Unfortunately, DOE funds are not adequate to support these needed experiments.

Experiments with a production model in the 12-ft wind tunnel could be linked to field tests on the same geometry. This will allow for the added benefit of relating wind tunnel drag to fuel economy. However, higher Reynolds number experiments with the GTS geometry provide for an expansion of the existing database for code validation with a simplified geometry. The NASA cost estimates include the possibility of performing the experiments with both a production model and the GTS model.

Jim also mentioned an interest in using the NASA computational tools to simulate the proposed experiments. Use of the NASA code OVERFLOW was proposed. The computational tool uses a RANS approach with structured-overset grids.

USC's Wind Tunnel Tests and a Look at an Aero Device

Fred Browand of USC provided a status report of recent experiments and analysis of results. The drag results obtained in the USC wind tunnel were compared to the NASA experiments at low Reynolds number, providing explanation for any discrepancies. It was noted that the base pressure is not changing much in the low Reynolds number regime so that the drag is dominated by the front curvature. At high Reynolds number, the GTS

geometry drag is all base drag so that there is significant leverage for improvement with wake conditioning.

Fred also present some preliminary results using an oscillation device to control the trailer wake flow. The device alters the turbulent structure of the wake resulting in a drag reduction. Proof-of-principal experiments are needed to determine the benefits of the oscillation device for drag mitigation.

Computational Model Development and Simulations

RANS Computations at SNL

An overview of the Reynolds-averaged Navier Stokes (RANS) computation being performed by SNL was presented by Kambiz Salari. Current efforts involve the modeling of the NASA experiments in the 7-ft x 10-ft wind tunnel.

To determine the appropriate inflow conditions for the computations, the empty tunnel was fully modeled and computed velocities were compared to those measured in the empty 7-ft x 10-ft wind tunnel. The computed and experimental velocity profiles at the test section entrance are in agreement and an adequate entrance and exit section for the computations was identified. Questions were raised as to how the pressure coefficient should be computed to be consistent with experiments.

The RANS one-equation Spalart-Allmaras turbulence model captures accurately the measured surface pressure coefficient at 0-degrees yaw for the GTS geometry. The calculations and the experiments indicate attached flow at the sides of the model for 0-degrees yaw. Some discrepancies between the computed and experimental pressure coefficient were present on the rear of the truck for 0-degrees yaw. At 10-degrees yaw, particle trace plots of the computations indicate the flow roll-up over the top of the vehicle as observed with pressure-sensitive paint (PSP) and oil-film interferometry (OIF) measurements in the wind tunnel. Details are provided in the enclosed viewgraph presentation.

Large-Eddy Simulations using the Finite Element Method at LLNL

The large-eddy simulation (LES) approach being used by LLNL was presented by Tim Dunn for both their compressible and incompressible flow models. The approach and development challenges were presented along with a progress update. Implementation of the incompressible model is complete and some validation remains. See attached viewgraphs for details on the models.

Dan Flowers of LLNL presented preliminary results using the compressible model for the GTS geometry for 0.3 and 2.4 million elements at 0-degrees yaw. A method for ease in grid refinement by using a separate near-body grid that boxes the vehicle was also presented. The computations with the course grid indicate higher drag results than measured, however, grid refinements show a trend towards the experimental results. The computed dominate pressure frequency with the 0.3 million element grid compares to that measured

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with the unsteady pressure probe mounted on the rear of the GTS. Further details are provided in the enclosed viewgraph presentation.

Simulations using Vortex Methods: A Gridless Technique

The Caltech group continues to improve their fast, parallelized, adaptive vortex method. Current activities at Caltech include: incorporating bodies with arbitrary complexity, obtaining higher Reynolds numbers computations, and developing and analyzing subgrid models for large-eddy simulation. Mark Brady of Caltech provided an overview of the vortex method approach and described a new technique for incorporating arbitrary sized body-surface triangles which has been recently implemented. This technique maintains computation accuracy while improving performance. Also a geometry definition similar to the GTS model (cab and trailer) has been defined and tested. Simulation Reynolds numbers are still quite low but plans are to move into the higher Reynolds number regime with the addition of subgrid scale models. Tony Leonard of Caltech presented his work in developing subgrid scale models for near-wall turbulence for use with large-eddy simulation. Several approaches for subgrid modeling for turbulent boundary layers have been identified for further developement.Further details and results of computations with the vortex method code and on the turbulence modeling approach are in the attached viewgraphs.

Future Meetings

The next Working Group Meeting will likely be in July or August 2000. The location of the next meeting has not yet been established.

Action Items

The follow-on action items with the individuals responsible for the tasks are as follows:

Response to DOD and DOE request for proposals (R. McCallen)

Proposal submission to BES and NSF (F. Browand and A. Leonard)

Paper and presentation at SAE Government Industry Meeting in Washington, DC in June 2000 (R. McCallen)

Meeting report with viewgraphs (R. McCallen)

Quarterly report due April 15, 2000 (R. McCallen)

Establish location and schedule next working group meeting (R. McCallen)